Transport Properties of Granular Metals

Scientific Achievement

Artificial materials composed of metallic nanoparticles or quantum dots have emerged as the next frontier of new materials where quantum phenomena can be tailored to generate novel bulk materials behavior. Our theoretical studies demonstrate that these nanosolids can have programmable electronic properties arising from the fact that the interaction strength and degree of disorder in these materials can be controlled by varying the size and composition of the granules. Each building block (grain or dot) of these new materials can be viewed as a tiny cluster of atoms of metallic or semiconducting elements. These clusters are not as small as molecules but not as large as macroscopic samples. Electrons in a single cluster are modeled as being confined in a box and therefore their energy levels are discrete. We developed a theoretical framework that can classify the novel bulk behavior of these granular nanosolids based on the coupling between the grains or dots: nanosolids with strong coupling (large tunneling conductance, g_T 1) exhibit metallic behavior, while materials with $g_T \leq 1$ are insulating. We constructed a phase diagram in the coordinates temperature T versus tunneling conductance g_T and formulated a complete description of the transport properties of these granular nanosolids composed of metallic nanoparticles or quantum dots.

Publications: I.S. Beloborodov, K.B. Efetov, A.V. Lopatin, V.M. Vinokur, Physical Review Letters, v.91, p.246801 (2003)

T.B. Tran, I.S. Beloborodov, X.M. Lin, T.P. Bigioni, V.M. Vinokur, Physical Review Letters, v.95, p.076806 (2005)

Significance

Our theoretical understanding of the transport properties of these quantum dot nanosolids will have far reaching consequences in the emerging nano-electronics industry as these artificial materials could constitute the main building blocks of future quantum electronics and spintronic devices. Furthermore, new fundamental quantum phenomena such as Coulomb blockade effects, which are predicted to occur in these nanosolids may have prospect for their applications in novel quantum memory devices and quantum computers.

Performers

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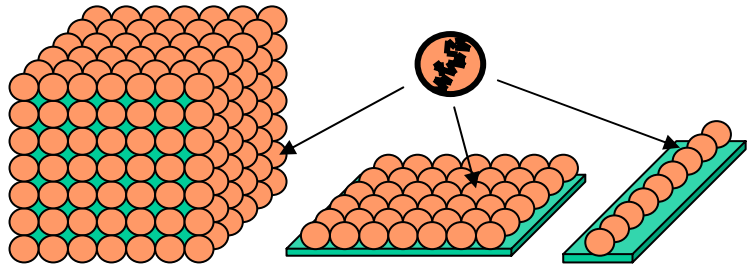
Transport Properties of Granular Metals

Motivation :

Creation of new artificial materials with programmable electronic properties



Open questions :

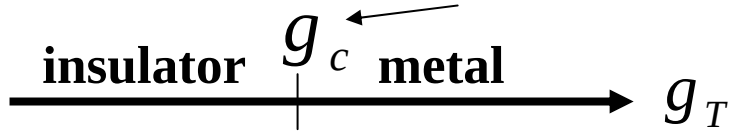
1. Understand the role of morphology on transport properties.
2. Explain hopping and logarithmic temperature dependences of granular metals.

Granular Metals characterized by two conductance's :

g_0 - grain conductance

g_T - tunneling conductance

Different transport regimes:



Future directions:

1. investigation of *hybrid* nanocrystals made of superconductor/ferromagnet grains
2. synthesis of novel superconducting nanocrystals in the 5-10nm size range

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